

Chapter 2:

The Energy and Environmental Lifecycle of First Generation and Advanced Biofuels

Energy production and use is central to our economy and way of life, but can also cause environmental harm in the form of air and water pollution, land degradation, and damage to wildlife and biodiversity. Burning of fossil fuels (coal, oil, natural gas) for electricity generation, space heating, industrial processes, and transportation causes air emissions that harm human health in the U.S. (the effect of so-called “criteria” air pollutants such as sulfur dioxide, nitrogen oxides, particulates, and carbon monoxide). Fossil fuel combustion is also by far the dominant source of emissions associated with global climate change, with carbon dioxide the primary greenhouse gas.

Biofuels can replace a portion of the petroleum and other fossil fuels that we use, and have the potential to mitigate some of the pollution caused by fossil fuel combustion. It is because of this that biofuels have received so much attention as part of a portfolio of strategies to reduce fossil fuel-based emissions. However, the effect of such replacement on emissions is far from a settled question.

Evidence to date indicates that, depending on the particular fuel and conversion process, the use of biofuels can increase, decrease, or hold roughly constant various air pollutants. In regard to greenhouse gas emissions, the present state of research indicates that, depending on what feedstocks are used, how they are processed, and how their cultivation affects land use worldwide, increased use of biofuels could either reduce or raise emissions. Furthermore, this research is by no means complete. For instance, there has been little analysis of the positive greenhouse gas impact that could be

achieved by protecting land and changing its use from potential sprawl development into production of woody biomass feedstock—an impact of particular interest in a region like the Northeast, which could provide significant cellulosic feedstock from the careful harvesting of forested land.

Unlike other renewable energy sources like wind and solar, the greenhouse gas impact of biofuels is complicated. When a biofuel such as ethanol or biodiesel is burned, carbon dioxide is released, just as it is with fossil fuels. Unlike fossil fuels, however, the crops, grasses, or trees from which biofuels are derived can be replanted and grown again. When plants grow, they absorb carbon dioxide, thus potentially canceling out the emissions that occur when they are burned. This potential is dependent, however, on whether harvesting and replanting are done sustainably, with crops consumed for energy continuously being replaced with equivalent new crops.

Both fossil fuels and biofuels require energy and create pollution not only when burned, but throughout their lifecycles. Fossil fuels must be extracted from the ground, transported, processed or refined, and then burned to release their energy. For biofuels, energy crops must be grown, harvested, transported, and processed into fuels before being burned for energy. Plant crops are a particularly “dispersed” source of energy, requiring large expanses of land to produce the volumes of feedstock needed. Some feedstocks, particularly corn and certain



other food crops, also require carbon- and chemical-intensive inputs, such as fertilizers and pesticides, to grow well. Converting feedstocks into ethanol and biodiesel is also energy intensive.

In addition, demand for fuel crops puts pressure on the world's supply of food, raising food prices and shifting previously uncultivated land into food production, with consequences for greenhouse gases. For example, if forests are cut down to plant crops, large volumes of

carbon that were contained ("sequestered") in the soil may be released. This happens in several ways. First, trees and plants may be burned to clear the land, causing large short-term emissions of carbon dioxide. Second, dead trees and plants decompose, gradually releasing carbon dioxide and

in some cases methane, another greenhouse gas. Third, there is actually more carbon in the soil itself than in all the trees, plants, and atmosphere above the ground. When soil is disturbed to grow crops, oxygen becomes available to it, stimulating biological activity that once again converts carbon into carbon dioxide.¹

Besides greenhouse gas emissions, the lifecycles of both petroleum and biofuels contribute to other air pollutants, as well as to water pollution from exploration, drilling, transportation, growing, processing, and use. Of particular concern with biofuels is runoff of fertilizer and pesticides into rivers and other water bodies, and subsequent pollution of downstream resources. Corn production in the Midwest, for instance, deposits fertilizer into the Mississippi River and is blamed for creating a large and growing "dead zone" in the Gulf of Mexico. Such problems could escalate as production volumes increase, and as crop prices rise due to higher demand, leading to more intensive use of fertilizer to increase yields per acre. Apart

from pollution, increased water use may also be a problem for both corn-based and cellulosic ethanol production as water supplies become tighter around the country.

At the same time, greenhouse gas emissions, water use, and pollution related to petroleum are likely to increase as oil is extracted from more difficult sources, such as Canadian tar sands—as is projected to happen as worldwide demand for oil continues to increase and ever-higher prices make such oil sources economic to develop. These impacts are relevant in comparing the environmental lifecycles of biofuels and petroleum.

Analyzing Greenhouse Gases of Biofuels over their Lifecycles

Attempts to measure the full lifecycle greenhouse gas impacts from biofuels in comparison with petroleum have given rise to a number of analytical models. Until recently, however, these models did not take into account the indirect impacts of changes in land use caused by increased biofuels production. Two ways this can occur are (1) higher demand and prices for corn (whose production is energy-intensive) cause land to be shifted from other, less energy-consuming crops, and (2) use of crops for fuel in one location causes land to be converted from non-crop to crop use elsewhere.

Earlier analysis indicated that corn-based ethanol yielded moderate but significant reductions—on the order of 20%—in greenhouse gas emissions relative to petroleum. Soybean-based biodiesel was estimated to yield greater savings, close to 70%. The inclusion of indirect land use impacts changes these equations dramatically, however, with recent research estimating that use of corn ethanol and crop-based biodiesel could yield large increases in net greenhouse gas emissions compared with petroleum.



Impacts Without Considering Indirect Land Use Change

Without considering indirect land use impacts, researchers agree that the currently dominant biofuel in the U.S., corn-based ethanol, yields a relatively small reduction in greenhouse gas emissions compared with petroleum, due to the high inputs of energy needed to grow, process, and transport it. The U.S. EPA, utilizing the GREET model developed by Argonne National Laboratory, estimates that corn ethanol yields a 22% reduction in greenhouse gas emissions over its lifecycle.²

Even that impact depends on what fuel source is used to process the corn into ethanol—natural gas, coal, or waste byproducts from the corn itself—and on other aspects of production. The Natural Resources Defense Council examined ethanol produced under a variety of conditions and found that, with coal used as the fuel source for processing, total emissions were slightly higher than for gasoline. However, with several improvements—including use of waste biomass for processing, locating the plant near a livestock farm so that the byproducts can be sold in a wet form and employment of low-till agriculture—the net benefits from corn ethanol relative to petroleum could be increased to well above EPA’s 22% estimate.³

To be eligible for the biofuel volume mandates of the recently passed federal law, the Energy Independence and Security Act of 2007, corn-based ethanol from new plants must yield a 20% reduction in greenhouse gas emissions. The law requires that both direct and indirect impacts, including indirect land use, be included in the analysis. However, there are provisions in the law that leave great uncertainty concerning the actual reductions that will occur. First, the U.S. Environmental Protection Agency (EPA) administrator has discretion to reduce the requirement to as little as 10%. Second, existing plants do not have to meet the 20% requirement, and the law does not prevent large expansions in the output of these plants.⁴

In comparison with corn ethanol, soybeans require far less fertilizer, pesticides, and water to be grown and turned into biodiesel. Per unit of energy gained, biodiesel requires only 1% of the nitrogen, 8.3% of the phosphorous, and 12% of the pesticides by weight used for the growth of corn-based ethanol.⁵ As a result, biodiesel has far less fossil-fuel energy embodied in its lifecycle. Without consideration of indirect impacts from land use and other factors, the EPA estimated a 68% reduction in greenhouse gas emissions relative to petroleum diesel.

The Energy Independence and Security Act of 2007 includes provisions stating that fuels eligible for its mandates can only be derived from feedstocks grown on land that was cleared for crops or for tree plantations prior to enactment of the law. This definition of “renewable biomass” would appear to prevent direct conversion of forests to fuel production from being eligible.⁶ The provisions would not address the “indirect” impacts discussed below.

The 2007 Act contains separate definitions for “advanced” and “cellulosic” biofuels. “Advanced” fuels are defined as those yielding lifetime greenhouse gas reductions of 50% or more. Since estimates of these reductions are in early stages of development, we do not yet know which biofuels will qualify. In particular, soy-based biodiesel would meet this threshold if indirect impacts on land use changes are excluded or turn out to be small, but may not qualify as “advanced” if research determines that substantial indirect land use impacts should be included.

Biofuels derived from cellulosic materials, such as cellulosic ethanol, promise much greater reductions in greenhouse gas emissions than do food-crop biofuels such as corn ethanol—and with fewer environmental costs. To qualify as cellulosic biofuel under the 2007 federal energy law, fuels must yield 60% or greater lifetime greenhouse gas reductions, including direct and indirect impacts. Cellulosic feedstocks include switchgrass, woody plants, agricultural waste

When plants grow, they absorb carbon dioxide, thus potentially canceling out the emissions that occur when they are burned. This potential is dependent, however, on whether harvesting and replanting are done sustainably, with crops consumed for energy continuously replaced with equivalent new crops.

New crops and conversion technologies are developing rapidly that will make it easier to produce lots of biofuels with a smaller environmental footprint, but the technologies are not a guarantee of good environmental performance. We need strong environmental safeguards and performance standards guiding the market so that innovation and competition will drive biofuels to provide the greatest benefits.

—Nathanael Greene, *Natural Resources Defense Council*

(for example, from cranberry production) and various prairie grasses, all of which require far less energy-intensive inputs than do food crops. One analysis that did not take into account indirect land use changes estimated that combustion of cellulosic ethanol only results in 1.9 pounds of net carbon dioxide emissions per gallon, a reduction of over 90% compared with conventional gasoline.⁷ It should be noted that these numbers are subject to uncertainty, since cellulosic ethanol has not yet reached commercial production and the technology behind it is rapidly evolving.

A key advantage of cellulosic feedstocks, and one that is agreed upon by a wide variety of studies, is their ability to thrive on agriculturally marginal lands that don't compete with food production for land use, and have the potential to deliver significant greenhouse gas reductions. However, it is possible that land currently producing food crops could be converted to energy crops, in which case the issue of global land use changes, and the associated dangers of large increases in greenhouse gas emissions and disruption of food supplies, would remain serious problems.

Indirect Impacts from Land Use Changes

In addition to greenhouse gases associated with crop growth and processing into biofuel, environmental impacts occur when areas such as forests or grasslands are converted into cropland. Such conversion releases large amounts of carbon from the soil, while the trees and grasses that had absorbed carbon dioxide are removed (although the new fuel crops will absorb some of this gas as well). Depending on the prior use of the land, the carbon releases can be very large relative to reductions in use of fossil fuels, resulting in what some researchers have termed a “carbon debt.”

Land use impacts can be direct or indirect. Direct impacts take place when land is converted from non-crop use in order to produce biofuel feedstock. Two causes of

indirect impacts are when existing cropland is converted from one crop to another, or when cropland is used for fuel instead of for food, creating the need to till other land for food crops. The effect of these shifts in use may not be apparent on a local, state, or even national level, but on a global scale could reduce food supplies and raise prices as land is converted from forest or grassland to crops—or food crop to fuel crop—in places around the world.

The first cause of conversion may result from increases in the price of one crop, causing farmers to shift toward that crop. For example, as ethanol demand has risen so have corn prices, causing a recent substantial rise in the U.S. acreage planted. At the same time, U.S. soybean acreage has fallen, possibly due to conversion to corn. Since corn requires far more energy in its lifecycle, this shift results in higher greenhouse gas emissions.

In regard to conversion from food to fuel crops, a recent study by the European Organization for Economic Cooperation and Development finds that biofuels have probably had relatively small impacts on world food markets to date, but could have much larger impacts in the future. This study estimates that production of ethanol and biodiesel could increase 160% by 2016 to 125 billion liters. That would require “about one-third of cereal land in the United States and in Canada and about half of the cereal, oil seeds, and sugar beets land in the European Union,” causing “a major impact on agriculture commodities prices.”⁸

Some of the earliest work on greenhouse gas impacts from land use conversion was done by Dr. Mark A. Delucchi of the Institute of Transportation Studies at the University of California–Davis. Delucchi estimated that the conversion of forest soils to croplands leads to a decrease of carbon content in the soil by 40% to 50% over the course of a few years. Conversion of range to cropland can reduce the carbon content of soil by 20% to 40% over a similar

period. Conversely, cellulosic energy crops such as switchgrass or short rotation poplar plantations increase soil carbon content if they replace traditional row crops such as corn, but reduce carbon content in the soil if they replace forests.⁹

European consumption currently dominates world demand for biodiesel, which represented about 7% of world vegetable oil production in 2007.¹⁰ The vast majority of this comes from rapeseed oil grown in Europe, due to high subsidies for domestic production. But this demand has resulted in a shortage of domestic food oil supplies, leading Europe to double its imports of palm oil from 2000 to 2006.¹¹ Meanwhile, the cultivation of palm trees for their oil (most of the demand for which is unrelated to biodiesel at present) is already creating environmental impacts in Southeast Asia. The draining, deforestation, and burning of peat lands for palm cultivation is responsible for severe increases in carbon dioxide emissions in the region. In Indonesia, 44 million acres of forest have been cleared for palm plantations.¹² As a result, by 2007 Indonesia had become the world's third largest emitter of carbon dioxide, according to a study by Wetlands International and Delft Hydraulics, both based in the Netherlands.

Besides the possibility of exacerbating climate change, the use of large portions of the planet's arable land for fuel raises serious environmental and economic justice questions. To the degree that total cropland is decreased and not replaced by conversion of other land, the world's food supply could fall, raising food prices and damaging living standards, particularly in low-income nations.¹³ On the other hand, the Worldwatch Institute has argued that higher prices for crops benefit poor farmers, who have been harmed by U.S. and European crop subsidies that lead to low prices.¹⁴

In regard to impacts on food supplies, most researchers expect cellulosic biofuels to yield much better results than corn ethanol and soy

biodiesel, since they do not necessarily depend on diverting food crops to fuel. If cellulosic fuel comes from materials such as wood waste or from sustainably managed grasslands and forests, emissions due to land use changes could be insignificant. But much will remain unknown about the impacts on land use until such fuels are produced on a large scale.

Dr. Delucchi developed the LEM model to estimate lifecycle greenhouse gas emissions from fuels. As of this writing, the model is incomplete and Delucchi's research is ongoing. He did, however, present preliminary results to the California Air Resources Board in June, 2007, stating a broad range of uncertainty in the numbers. Delucchi estimated that corn ethanol could yield between a 25% decrease and a 20% increase, soy biodiesel between a 20% decrease and a 50% increase, and cellulosic ethanol between a 75% decrease and a 40% decrease in greenhouse gas emissions. Besides indirect land use changes, Dr. Delucchi also highlights the importance of the analysis of non-carbon dioxide greenhouse gases, including nitrogen dioxide and ammonia.¹⁵

Other recent analysis conducted by researchers at the University of California–Berkeley on behalf of the California Air Resources Board finds that indirect land use impacts could dominate all other factors in the carbon lifecycle of crop-based biofuels.¹⁶

Table 2.1 above summarizes the UC-Berkeley research. Accounting for indirect land use changes dramatically alters the greenhouse gas equation, causing the overall results for crop-based ethanol and biodiesel to be worse than for petroleum-based gasoline or diesel fuel (although, as discussed below, the petroleum fuel numbers do not include indirect impacts).



Table 2.1: Greenhouse Gas Impacts of Biofuels, Direct and Indirect					
Grams CO2 equivalent/megajoule energy output					
	Gasoline	Midwest Corn Ethanol	Calif. Ultra Low Sulfur Diesel	Canola Biodiesel	Renewable Diesel (Palm)
Direct Emissions	94	88	93	32	21
Indirect Emissions from Land Use Change		140 (CRP*) to 540 (tropical rainforest)		1,031 (tropical rainforest**)	197
Total Emissions	94	228 to 628	93	1,063	218
*CRP is the U.S. Conservation Reserve Program, through which marginal agricultural land is kept out of production.					
**Indirect impacts from use of canola biodiesel (the primary feedstock in Europe) are much higher than for palm biodiesel per gallon of fuel, even though both may cause tropical rainforest conversion to palm trees, because palm trees yield several times more oil/acre than canola (rapeseed).					

In terms of direct emissions, which don't include the full spectrum of possible land use changes, corn ethanol produces on the order of 20% less greenhouse gas emissions than gasoline, while biodiesel results in one-third the emissions of petroleum-based diesel. But when land use changes are added to the equation on the biofuels side, corn ethanol produces at least twice as much greenhouse gas as gasoline, while biodiesel produced from U.S. feedstocks could be 10 times as large a greenhouse gas producer as petroleum diesel.

It should be recognized that these are worst-case results, since they assume that converting one acre of food crops for fuel results in converting an additional acre of uncultivated land to food crops. To the degree that the global demand for food falls as prices rise (with possibly harmful effects on human welfare) or productivity per acre increases, land use impacts would be reduced.

Also, it is important to recognize that the studies discussed above, and the U.S. Department of Energy's GREET model, have not analyzed the indirect lifecycle impacts from extracting and refining petroleum on land use and possibly other factors. Greenhouse gas emissions and other environmental costs from petroleum are likely to increase as oil is increasingly extracted from more difficult sources, such as Canadian tar sands. Analysts have estimated that, on a full lifecycle basis, use of tar sands results in about one-fifth more

emissions per gallon of fuel than conventional gasoline.¹⁸ This is because, although most emissions due to oil take place when the fuel is burned during consumption, greenhouse gas emissions during extraction and refining of oil from tar sands are three times as high as those from producing conventional gasoline, according to one study.¹⁹ In addition, tar sand extraction involves heavy use of water and land degradation.²⁰

Analysis along the same lines as that conducted by Dr. Delucchi and by the UC-Berkeley researchers was recently published in *Science* magazine, showing similar results. The authors found that while, based on the GREET model, corn ethanol yielded a 20% reduction in greenhouse gas emissions versus gasoline, accounting for indirect land use changes resulted in a 93% increase in emissions. Furthermore, they argued that high levels of biofuels production from crops could lead to increases in the prices of corn, wheat, and soybeans.²¹

The U.S. Department of Energy, which developed the GREET model, the New Fuels Alliance, and several other groups have responded to the *Science* article taking issue with both the methods and results. They argue several points: (1) that the primary assumption of 30 billion gallons per year of corn ethanol (five times current use and twice the amount called for by federal law by 2022) is far too high, creating potentially amplified land use

impacts; (2) that the treatment of yield increases is inaccurate; (3) that their assumptions about what kind of land would be converted is pessimistic; and (4) that the full lifecycle impacts of petroleum have not been included in the calculations.^{22, 23}

Dr. Wang, the primary developer of the GREET model and author of the U.S. DOE response to *Science*, further claimed that there is no indication that corn exports from the U.S. have declined, which makes the core of the argument that foreign lands are being converted premature. And Dr. Delucchi of UC-Davis stated, “[i]n sum, these studies highlight an important (and generally well known) effect of the development of biofuels, but leave out a great many important factors, and do not tell us anything definitive about the overall impact of biofuels on climate.”^{24, 25}

The *Science* article authors have responded to the critiques of their analysis.²⁶ They note, for example, that one reason corn exports have not fallen is because U.S. acreage planted in corn rose 18% from 2006 to 2007, in response to ethanol demand and higher prices.²⁷ In turn, soybean acreage fell sharply. The authors of the UC-Berkeley study and the *Science* article are also of the opinion that indirect petroleum impacts on land use will be relatively small compared to those for biofuels.²⁸ Several studies are currently investigating the indirect impacts of petroleum production, including, but not limited to, land use.

As this debate shows, the scientific research on these questions is unsettled at present. Clearly, the indirect greenhouse gas impacts (including, but not limited to, land use) from petroleum should be calculated and included in any comparison of fuel sources, and the results of research in this area should be included in Massachusetts’s regulatory framework as they become available (see discussion of a Low Carbon Fuel Standard, Chapter 4).

While comparing alternatives based on projected future emissions impacts is important, one primary goal is to cut greenhouse gas emissions from current levels. The Energy Independence and Security Act of 2007 defines “renewable fuel,” “advanced biofuel,” and “cellulosic biofuel” as meeting percentage lifecycle greenhouse gas reductions in relation to a “baseline” representing average emissions from gasoline or petroleum diesel fuel in the year 2005—not in relation to a future scenario in which oil shale or tar sands are dominant sources of supplies.²⁹

If it turned out that petroleum from shale oil or other highly damaging future sources has higher emissions than crop-based biofuels, but that crop-based fuels raise emissions relative to current gasoline and diesel fuel, then neither fuel source would be acceptable from a climate change perspective. Instead, we would need to strengthen our focus on other solutions, including electric vehicles, vehicle efficiency, emerging low carbon fuels (if available), and reducing vehicle miles traveled.

Importantly, most analyses to date project that cellulosic-based biofuels will yield major reductions in greenhouse gas emissions relative to current petroleum fuels. The analyses include those of Dr. Delucchi, the U.S. Department of Energy, and the U.S. EPA, all discussed above.³⁰

How best to evaluate the full lifecycle impacts of alternative fuel sources—particularly relating to land use—is a new and evolving field. None of the results published so far are definitive, and further research is being done by California, the U.S. EPA, the European Union, and various academic researchers. Much of this research will not be available until the end of 2008 or later. Until a scientific consensus is established, much will remain uncertain about the greenhouse gas impacts of biofuels and all other fuels, including petroleum, over the course of their lifecycles.

Biofuels derived from cellulosic materials, such as cellulosic ethanol, promise much greater reductions in greenhouse gas emissions than do food-crop biofuels such as corn ethanol—and with fewer environmental costs.

UMass-Amherst, MassHighway, the Massachusetts Water Resources Authority and the City of Boston all use thousands of gallons of biodiesel blends from 5% to 20% in their fleets every year—with no adverse effects on their vehicles, resulting in significant reductions in carbon monoxide, particulate matter, and sulfates, as well as hydrocarbon and air toxics emissions.

—Massachusetts
Leading by
Example
Program, EEA

Criteria Air Pollution, Water Pollution, and Water Use

Greenhouse gas emissions are not the only environmental impacts of both fossil and renewable fuels. Burning fuel results in emissions of various other pollutants and biofuels should be compared with petroleum-based fuels on this basis as well. In addition, there could be far-reaching environmental impacts of withdrawing water from potentially stressed water sources. Wastewater impacts also require adequate analysis.

Air Pollution

Blending ethanol with gasoline at low levels as an oxygenate (as is done in Massachusetts to comply with reformulated gasoline requirements) uses ethanol in, at most, a 10% blend (E10) in place of MTBE (an additive that caused water pollution problems). E10 decreases most air pollutants, such as carbon monoxide, yielding significant public health benefits. Ethanol can, however, exacerbate hydrocarbon emissions due to its volatility at low percentage blends. For E85, most analysis indicates that criteria air emissions are generally similar to those for gasoline.³¹ One study, however, suggests that use of E85 could raise formaldehyde and acetaldehyde levels nationally, and ozone levels in some regions of the country.³² Since cellulosic ethanol is chemically identical to ethanol from food crops, air emissions from burning it are expected to be the same as from use of corn-based fuel.

The manufacture of ethanol is regulated much like a chemical plant because it emits VOCs (volatile organic compounds), which are precursors to ground level ozone and air toxics such as acetaldehyde. These air pollutants are tightly regulated in Massachusetts because the state does not meet national health-based standards for ozone. Depending on the size of a facility, the level and complexity of potential air quality emissions will vary.

Biodiesel combustion results in reduction of most air pollutants (particulate matter, carbon monoxide, hydrocarbons, sulfates, and air toxics) compared with petroleum diesel, according to current EPA testing, but causes some increase in nitrogen oxides (a precursor to smog) when used as a motor vehicle fuel in higher level blends.³³ Further research is being conducted due to conflicting data, since other rigorous studies have shown no increase in nitrogen oxides or a decrease when compared to burning diesel.³⁴ However, when used in combination with Number 2 oil as a heating fuel, nitrogen oxide emissions do not rise and may fall, while emissions of other pollutants are reduced significantly.^{35 36}

The potential use of waste material, including construction and demolition debris and other urban waste, municipal solid waste, sewage sludge and other waste feedstocks in the production of biofuels raises concerns over releases of heavy metals and other contaminants. More information is needed to understand and evaluate the potential effect of such uses on human health and the environment.

Water Pollution

Biorefineries require water to convert biological materials into fuel and this water must be treated and discharged as a waste product.

Corn production requires large amounts of nitrogen, phosphorus, and pesticide inputs, as well as fertile land. These fertilizers and pesticides can be transported by leaching and surface flow to surface, ground, and coastal waters, resulting in eutrophication, loss of biodiversity, and elevated nitrate and nitrite levels in drinking water.

Because biodiesel crops use smaller amounts of fertilizer, pesticides and water in production compared with corn, their impacts on water supply and quality are much less significant.³⁷ Waste products include glycerin and about one

gallon of water discharge for each gallon of biodiesel produced. There is a market for the glycerin byproduct as animal feed, anaerobic digestion enhancement, and potential use at wastewater treatment plants to accelerate denitrification. Since the byproducts of biodiesel and ethanol have value, new refining processes are being used to maximize recovery. Wastewater from biodiesel refineries can be high in grease and oils resulting in a biological oxygen demand that can damage aquatic environments if not properly treated.

Cellulosic ethanol feedstock can be produced with little or no fertilizer or pesticides and requires less water than other biofuel crops. Cellulosic biorefineries do, however, have brine discharges and the production process produces wastewater that can kill aquatic life unless adequately treated before it is discharged.³⁸

As with any manufacturing plant, ethanol plants and biorefineries have the potential for spills and leaks during the refining process and from chemical and product storage tanks.

Water Use

Ethanol production consumes water through evaporation during distillation and for cooling towers. Cellulosic ethanol can consume two to six gallons of water per gallon of ethanol produced, while corn ethanol production consumes four gallons of water per gallon of ethanol.³⁹

Biodiesel refineries proposing to locate in Massachusetts have described limited water withdrawal needs for the refining process, since they have selected new technology that reduces water consumption. Water at these facilities is mainly used as tank wash water or to mix with concentrated acid or alkaline catalysts for the refining process (one company estimates 0.1 gallon of water per gallon of biodiesel in their refining process), with some water demand for heating or cooling.⁴⁰ Other sources claim a demand of one gallon of water per gallon of biodiesel.⁴¹ It is important to note, however,

that petroleum extraction and production also require large volumes of water.

Policy Recommendations

The European Union's experience in alternative fuel policy illustrates the need for care in choosing which feedstocks and biofuels to use and which deserve government support. The EU mandated that, by 2010, biofuels should represent 5.75% of all transportation fuels as part of a larger agenda of increasing the ratio of renewable energy in the domestic energy supply.⁴²

Subsequently, lifecycle analysis made it clear that biofuels vary in their impact on carbon emissions.

As a result, European countries are now in the process of creating a certification protocol to require that biofuels have a certain percentage lower emissions than conventional fuel to qualify for government subsidies. For example, Sweden has proposed that biofuel would have to produce 40% less greenhouse gas emissions than conventional fuel to qualify for government support. Other proposals aim to prohibit the import of biofuels grown on certain types of land, such as wetlands or rainforests. Such regulations would primarily affect palm producers in Southeast Asia and sugarcane producers in Brazil.⁴³

Seeking to avoid problems encountered in the European experience, federal energy legislation recently passed by Congress, the Energy Independence and Security Act of 2007, does address the connection between land use change and greenhouse gas emissions, requiring that, to



qualify for the production mandates established by the law, biofuels must meet specific direct and indirect lifecycle greenhouse gas emission reduction targets. For first-generation biofuels (primarily corn ethanol) the requirement is 20%; “advanced biofuels” (including biodiesel) must meet a 50% reduction target; and cellulosic fuels must be 60% below petroleum.⁴⁴

Both the California Air Resources Board (as part of developing regulations for its Low Carbon Fuel Standard) and the U.S. EPA (as part of developing regulations to enforce the greenhouse gas and land use requirements in the federal energy law) are in the midst of intensive efforts to evaluate the lifecycle impacts of all fuels that could power motor vehicles.

In view of these efforts, the Massachusetts Advanced Biofuels Task Force recommends the following:

1. Develop standards for lifecycle evaluation that consider the carbon and environmental impacts of biofuels, including potential impacts on agricultural, forest, and other land use in Massachusetts and on a global basis, using definitions similar to those employed in California and included in the new federal energy law. These evaluations must include both direct and indirect impacts, as well as consideration of impacts on environmental justice. Due to the complexity of lifecycle analysis, to the extent possible, Massachusetts should make use of analyses done by other parties, including the California Air Resources Board, the U.S. EPA, and the European Union.
2. Lifecycle evaluation methods should put biofuels, petroleum fuels, and other energy sources for vehicles (such as electricity and hydrogen) on a level playing field, assessing secondary and indirect impacts for all.
3. To receive state support for biofuels development and/or use, a particular biofuel must provide a substantial reduction in greenhouse gas emissions relative to petroleum fuels on a lifecycle basis.
4. The state should ensure that developers of refineries meet stringent water discharge limits and select technologies that reduce water needs.
5. Since biofuels made from in-region waste materials, such as waste oils, are likely to have lower greenhouse gas emissions than biofuels from virgin materials, state agencies should have the latitude to exempt fuel produced from waste materials from a full lifecycle greenhouse gas emissions analysis. However, state agencies should require a review that considers the highest reuse option for the waste feedstock (including recycling) and conduct appropriate environmental reviews of biofuel production processes that seek to minimize potential air and water impacts, as well as chemical and energy use.
6. Support the development and implementation of fuel quality standards (for example, federal ASTM standards) to provide consumer assurance of reliability of advanced biofuels.

Chapter 2 Endnotes

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